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(54) (TITLE OF THE INVENTION) LIQUID LEAK DETECTOR

(57) (ABSTRACT)

(PROBLEM) To provide a liquid leak sensor that operates normally even when the ambient temperature of the sensor changes.

(MEANS FOR SOLVING) Heat quantity Q is supplied from heater 12 to temperature sensor for liquid leak detection 1. A constant amount of power that is input into power setter 15 is always supplied to heater 12 by power monitor 14 and power controller 16, and heat quantity Q is always constant. A difference in the corrected temperature and the present temperature is obtained by subtracting the reference value stored in reference temperature storage mechanism 4 of the temperature sensor for liquid leak detection at the time of correction from temperature sensor for liquid leak detection 1 with comparator 7. Likewise, a difference in the corrected temperature and the present temperature is obtained by subtracting the reference value stored in reference temperature storage mechanism 5 of the temperature sensor for ambient temperature measurement at the time of correction from temperature sensor for ambient temperature measurement 2 with comparator 8. By finding the difference between these temperature differences using comparator 10, it is possible to measure the change in thermal resistance in temperature sensor for liquid leak detection 1, and liquid leaks can therefore be detected.

(Representative Drawing) Figure 1

[see source for figure]

1 temperature sensor for liquid leak detection
2 temperature sensor for ambient temperature measurement
4 reference temperature storage mechanism of the temperature sensor for liquid leak detection
5 reference temperature storage mechanism of the temperature sensor for ambient temperature measurement
7 comparator
8 comparator
10 comparator
12 heater
13 current amplifier
14 power monitor
15 power setter
16 power controller
Q heat quantity
T0l – T0a ambient temperature difference
ΔT temperature difference

(SCOPE OF PATENT CLAIMS)

(CLAIM 1)

A liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids, said liquid leak detector characterized in that it has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for supplying a constant quantity of heat to said temperature sensor, and means for measuring the difference between the temperature measured by said temperature sensor and the temperature measured by said means for measuring the ambient temperature of the temperature sensor.

(CLAIM 2)

A liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids, said liquid leak detector characterized in that it has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for measuring the quantity of heat supplied to said temperature sensor, and means for measuring the difference between the temperature measured by said temperature sensor and the temperature measured by said means for measuring the ambient temperature of the temperature sensor.

(CLAIM 3)

A liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids, said liquid leak detector characterized in that it has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for maintaining the difference between the temperature of said temperature sensor and the ambient temperature at a constant level, and means for measuring the difference between the temperature measured by said temperature sensor and the temperature measured by said means for measuring the ambient temperature of the temperature sensor.

(DETAILED DESCRIPTION OF THE INVENTION)

(0001)

The present invention relates to liquid leak detectors that detects the leakage of liquids, which are used in analytical instruments such as liquid chromatographs or industrial instruments.

(0002)

(PRIOR ART)

There are liquid leak detection methods that detect electrical conductivity, methods that detect changes in the index of refraction, and methods that detect changes in heat dissipation (thermal resistance). Methods that detect electrical conductivity are advantageous in that the instruments used are simple and the sensitivity is high, but they are disadvantageous in that liquids with low electrical conductivity cannot be detected and that the sensitivity decreases with the contamination and corrosion of the electrodes that measure electrical conductivity. There are no restrictions regarding the types of liquids that can be detected with methods that detect the index of refraction, but they are disadvantageous in that the instruments used are complex. With methods that detect changes in heat dissipation, there are no restrictions regarding the types of liquids that can be detected and the instruments used are relatively simple, but there is the shortcoming that the sensor output changes with the ambient temperature.

(0003)

The basic principle of heat dissipation type liquid leak detectors is shown in Figure 4. A weak quantity of heat is applied to temperature sensor 41, which is a device such as a thermistor, and this is maintained at a higher temperature than the ambient temperature. The output voltage of temperature sensor 41 changes depending on the temperature, and it is compared to the reference voltage obtained by zero-point storage mechanism 45 with comparator 43. When the quantity of heat applied to temperature sensor 41 is Q (W), the thermal resistance with respect to the surrounding area when the sensor is surrounded by air is Ra (°C/W), and the ambient temperature is T0 (°C), the temperature of temperature sensor 41 reaches an equilibrium temperature with the heat quantity and thermal resistance. When the equilibrium temperature when the surrounding area is air is Ta (°C), the temperature of the temperature sensor is expressed by Formula (1).

$$Ta = T0 + Q \cdot Ra \quad \cdots\cdots\cdots (1)$$

This temperature Ta is stored in zero-point storage mechanism 45 as a reference storage value. Here, when the area surrounding temperature sensor 41 makes contact with a liquid, the thermal resistance of the liquid is generally smaller than that of the air, so the thermal resistance with respect to the surrounding area decreases. When the thermal resistance in the liquid contact state changes to Rb (°C/W), the temperature of temperature sensor 41 at this time changes to T1 in Formula (2)

$$T1 = T0 + Q \cdot Rb \quad \cdots\cdots\cdots (2)$$

Therefore, the temperature difference ΔT in Formula (3) occurs in contrast to the case in which the area surrounding temperature sensor 41 is air.

$\Delta T = T1 - Ta = Q\,(Rb - Ra)$ ········· (3)

By comparing T1 and Ta stored in zero-point storage mechanism 45 using comparator 43 and detecting this temperature difference ΔT, it is possible to use temperature sensor 41 as a liquid leak detector. In other words, after the sensor output of the case in which the area surrounding temperature sensor 41 is air is stored as a reference storage value, the value resulting when the reference value is subtracted from the present sensor output value is monitored, and if this value changes by a constant amount when contact is made with a liquid due to a liquid leak, for example, it is assessed that there is a liquid leak. The temperature difference was detected in this example, but this method operates in the same way when another measurement value correlated to temperature, such as thermistor resistance, for example, is detected.

(0004)

Information regarding literature on prior art related to the thermal emission detection type liquid leak detector described above was surveyed, but no such information was found.

(0005)

(Problem to be Solved by the Invention)

With the aforementioned method using the heat dissipation detection type liquid leak detector described above, a reference value is measured and stored when the area surrounding temperature sensor 41 is air, and this is used as a comparison reference value for when the surrounding area becomes a liquid, but this is based on the assumption that ambient temperature T0 does not change from when the reference value is stored and when the reference value is measured. In actuality, the ambient temperature does change, so recalculating Formula (3) with this in mind, the temperature difference ΔT for the temperature sensor 41 between the case in which the area surrounding the temperature sensor is a liquid and the case in which the area surrounding the temperature sensor is air is expressed by Formula (4) when the ambient temperature at the time of reference value storage is T0a and the ambient temperature at the time of measurement is T0I.

$\Delta T = (T0I + Q \cdot Rb) - (T0a + Q \cdot Ra) = (T0I - T0a) + Q\,(Rb - Ra)$ ········· (4)

That is, the measured temperature of temperature sensor 41 changes not only when a liquid is detected, but also when the ambient temperature changes. When such a sensor is used as a liquid leak sensor, malfunctions in which liquid leaks are reported when in fact there are no leaks or actual leaks cannot be detected arise in cases in which there are temperature changes.

(0006)

The following method can be considered as a means for solving such a problem. First, the quantity of heat applied to the temperature sensor is made large such that temperature changes (T0I – T0a) in the area surrounding the temperature sensor can be ignored. This method can be easily implemented, but because the temperature of the temperature sensor portion becomes high, there is the shortcoming that it cannot be used for flammable liquids. Next, there is a method in which the ambient temperature of the temperature sensor is measured, and temperature changes are corrected. With this method, it is possible to offset the effects of temperature changes in the area surrounding the temperature sensor with high precision without increasing the temperature of the temperature sensor, but another temperature sensor that measures temperature changes in the area surrounding the first temperature sensor becomes necessary.

(0007)

It is not possible to significantly increase sensor temperature with instruments such as liquid chromatographs that use organic solvents, so methods in which temperature changes are absorbed by temperature correction are effective in such cases. However, while Formula (4) is based on the assumption that the quantity of heat Q does not change from when the reference value is stored and when the reference value is measured, the quantity of heat generally changes in step with changes in ambient temperature. With this in mind, Formula (4) can be corrected and expressed as Formula (5).

$\Delta T = (T0I + Qb \cdot Rb) - (T0a + Qa \cdot Ra) = (T0I - T0a) + Qb \cdot Rb - Qa \cdot Ra$ ········· (5)

It can be seen here that correction is difficult when simply measuring the temperature of the area surrounding the sensor.

(0008)

The present invention was conceived in order to solve the aforementioned problem, and its purpose is to provide a liquid leak sensor that operates normally even when the ambient temperature of the sensor changes.

(0009)

(Means for Solving the Problem)

In order to solve the aforementioned problem, the liquid leak sensor of the present invention is a liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids which has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for supplying a constant quantity of heat to the temperature sensor, and means for measuring the difference between the temperature measured by the temperature sensor and the temperature measured by the means for measuring the ambient temperature of the temperature sensor.

A thermistor, thermocouple, or platinum resistor can be used as the temperature sensor. As the means for supplying a constant quantity of heat to the temperature sensor, there is, for example, the combination of a power setter that sets the quantity of heat to be supplied, a power monitor that measures the quantity of heat supplied, and a power controller that acts to eliminate the difference between the value set by the power setter and the value measured by the power monitor.

(0010)

Formula (4) can be modified and expressed as Formula (4′).

$Q\,(Rb - Ra) = \Delta T - (T0I - T0a)$ ········· (4′)

ΔT in Formula (4′) is obtained by subtracting temperature T0a of the temperature sensor when the reference value is stored at the time of correction from the present temperature T0I of the temperature sensor. Similarly, (T0I – T0a) in Formula (4′) is obtained by subtracting the reference value of the ambient temperature stored at the time of correction from the present ambient temperature of the temperature sensor. Q (Rb – Ra) can be found from these values. Heat quantity Q is controlled such that it is a constant value, so Q (Rb – Ra) is proportional to the change in the thermal resistance of the temperature sensor when the surrounding area is a liquid and when the surrounding area is air. It is therefore possible to detect liquid leaks by comparing this to the judgment standards.

(0011)

Moreover, the liquid leak sensor of the present invention is a liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids which has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for measuring the quantity of heat supplied to the temperature sensor, and means for measuring the difference between the temperature measured by the temperature sensor and the temperature measured by the means for measuring the ambient temperature of the temperature sensor. A power monitor, for example, can be used as the means for measuring the quantity of heat supplied to the temperature sensor.

(0012)

From Formula (1), the thermal resistance of the temperature sensor can be found as shown in Formula (6) when the quantity of heat at this time is Q and the ambient temperature is T0.

$R = (T1 - T0) / Q$ (°C/W) ········· (6)

The quantity of heat Q is found from the means for measuring the quantity of heat, so it is possible to find the change in thermal resistance and thus detect liquid leaks by finding the difference between the present thermal resistance and the thermal resistance when there are no liquid leaks.

(0013)

Furthermore, the liquid leak sensor of the present invention is a liquid leak detector that detects liquid leaks by measuring changes in the quantity of heat dissipation from a temperature sensor that is heated or self-heats to a higher temperature than the ambient temperature that result based on the presence or absence of liquids which has means for measuring the temperature of the temperature sensor and the ambient temperature of the temperature sensor, means for maintaining the difference between the temperature of the temperature sensor and the ambient temperature at a constant level, and means for measuring the difference between the temperature measured by the temperature sensor and the temperature measured by the means for measuring the ambient temperature of the temperature sensor. As the means for maintaining the difference between the temperature of the temperature sensor and the ambient temperature, there is, for example, the combination of two temperature detectors that measure the difference between the temperature of the temperature sensor and the ambient temperature, a temperature setter that sets the temperature difference in advance, and a heater drive circuit that controls the heater that supplies heat to the temperature sensor in order to eliminate the difference between the actual temperature difference and the preset temperature difference.

(0014)

Using the fact that the quantity of heat necessary to maintain the temperature of the temperature sensor at a constant level is equivalent to the quantity of heat dissipated, it is possible to detect liquid leaks without dependence on ambient temperature by measuring the heat dissipation. Formula (2) can be modified as shown in Formula (2′).

$T1 - T0 = Q \cdot Rb$ ········· (2′)

Here, when the difference between the temperature of the temperature sensor and the ambient temperature is the constant value ΔTs, (2′) is expressed as Formula (7).

$\Delta Ts = Q \cdot Rb$

$Rb = \Delta Ts / Q$ ········· (7)

In other words, it is possible to measure the thermal resistance Rb of the temperature sensor by measuring the quantity of heat (power) supplied to the temperature sensor. The change in thermal resistance is obtained by subtracting from this value the thermal resistance Ra, which is stored at the time of correction, of the case in which the area surrounding the temperature sensor is air, and it is possible to detect liquid leaks by comparing this to a certain threshold.

(0015)

(EMBODIMENT OF THE INVENTION)

Embodiments of the present invention will be described hereafter with reference to the drawings. A block diagram of an embodiment of the liquid leak detector of the present invention is shown in Figure 1. The liquid leak detector of the present invention comprises temperature sensor for liquid leak detection 1, temperature sensor for ambient temperature measurement 2, reference temperature storage mechanism 4 of the temperature sensor for liquid leak detection, reference temperature storage mechanism 5 of the temperature sensor for ambient temperature measurement, comparators 7, 8, and 10, heater 12, current amplifier 13, power monitor 14, power setter 15, and power controller 16. Temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 are thermistors.

(0016)

Heat quantity Q is supplied from heater 12 to temperature sensor for liquid leak detection 1. A constant amount of power that is input into power setter 15 is always supplied to heater 12 by power monitor 14 and power controller 16, and heat quantity Q is always constant. ΔT in Formula (4′) is obtained by subtracting the reference value stored in reference temperature storage mechanism 4 of the temperature sensor for liquid leak detection at the time of correction from temperature sensor for liquid leak detection 1 with comparator 7. Likewise, (T0I – T0a) in Formula (4′) is obtained by subtracting the reference value stored in reference temperature storage mechanism 5 of the temperature sensor for ambient temperature measurement at the time of correction from temperature sensor for ambient temperature measurement 2 with comparator 8. It is possible to find Q (Rb – Ra) from these values using comparator 10. Heat quantity Q is controlled such that it is a constant value, so Q (Rb – Ra) is proportional to the change in the thermal resistance of the temperature sensor for liquid leak detection 1 when the surrounding area is a liquid and when the surrounding area is air. It is therefore possible to detect liquid leaks by comparing this to the judgment standards.

(0017)

A block diagram of a second embodiment of the present invention is shown in Figure 2. This embodiment comprises temperature sensor for liquid leak detection 1, temperature sensor for ambient temperature measurement 2, thermal resistance reference value storage mechanism 23, comparators 25 and 29, thermal resistance finder 27, heater 12, and power monitor 14.

(0018)

The liquid leak detector of this embodiment detects liquid leaks by directly finding the thermal resistance of temperature sensor for liquid leak detection 1 using Formula (6). Heat quantity Q is supplied from heater 12 to temperature sensor for liquid leak detection 1. Heat quantity Q may fluctuate, but its value is constantly measured by power monitor 14. The temperature difference (T1 – T0) between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 is obtained by comparator 25, and the thermal resistance Rb to the area surrounding temperature sensor for liquid leak detection 1 can be directly calculated by dividing this by heat quantity Q calculated from the power found with power monitor 14 in thermal resistance finder 27. The present thermal resistance Rb is therefore compared to the thermal resistance Ra of the state in which there were no leaks, which is stored in thermal resistance reference value storage mechanism 23 at the time of correction, with comparator 29. The thermal resistance when the surrounding area is air is greater than the thermal resistance when the surrounding area is filled with a liquid, so it is possible to detect liquid leaks by assessing that there are leaks when Rb is less than 50% of Ra, for example.

(0019)

The configuration of power monitor 14 is shown in Figure 5. Power monitor 14 comprises resistance 51, thermistor 53, and voltmeter 55. Resistance 51 has the resistance value R. Thermistor 53 is pulled up by resistance 51 with voltage Vcc, and the thermistor voltage Vth at that time is monitored by voltmeter 55. In this circuit, the current Ith of thermistor 53 is expressed by Formula (8).

$Ith = (Vcc - Vth) / R$ ·········(8)

Therefore, the heat power Pth of thermistor 53 is found with Formula (9).

$Pth = Ith \bullet Vth = Vth (Vcc - Vth) / R$ ········(9)

Vcc and R are values that are determined in advance, so it is possible to constantly monitor the heat power Pth by measuring Vth with voltmeter 55.

(0020)

A block diagram of a third embodiment of the present invention is shown in Figure 3. This embodiment comprises temperature sensor for liquid leak detection 1, temperature sensor for ambient temperature measurement 2, heater 12, heater drive circuit 35, temperature setter 33, power monitor 14, heater resistance finder 27, comparators 30, 31, and 39, and thermal resistance reference value storage mechanism 23.

(0021)

The liquid leak detector of this embodiment is able to measure, using Formula (7), the thermal resistance of temperature sensor for liquid leak detection 1 by maintaining the temperature difference between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 at a constant level, and it detects liquid leaks using this value. Heat quantity Q is supplied from heater 12 to temperature sensor for liquid leak detection 1, and the sensor is thus maintained at a higher temperature than the ambient temperature. The temperature difference ΔTs between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 is constantly measured by comparator 30. The temperature difference between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 is set in advance by temperature setter 33, and the difference between the value set by temperature setter 33 and ΔTs measured by comparator 30 is measured by comparator 31. A signal from comparator 31 is transmitted to heater drive circuit 35, and the temperature difference ΔTs between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2 is controlled such that it always coincides with the temperature set by temperature setter 33. Moreover, heat quantity Q supplied to heater 12 is measured by power monitor 14, and the thermal resistance of temperature sensor for liquid leak detection 1 is calculated by thermal resistance finder 27 according to Formula (7) using this heat quantity Q and the temperature difference ΔTs between temperature sensor for liquid leak detection 1 and temperature sensor for ambient temperature measurement 2. The present thermal resistance Rb is compared to the thermal resistance Ra of the state in which there were no leaks, which is stored in thermal resistance reference value storage mechanism 23 at the time of correction, with comparator 39. It is possible to detect liquid leaks by assessing that there are leaks when Rb is less than 50% of Ra, for example.

(0022)

Embodiments of the present invention were described above, but the present invention is not limited to the aforementioned embodiments, and it is possible to make various modifications within the scope of the present inventions described in the Scope of the Patent Claims. For example, in the embodiments described above, liquid leaks are detected by measuring the thermal resistance of temperature sensor for liquid leak detection 1, but it would also be possible to detect liquid leaks by measuring thermal conductivity. In this case, the thermal conductivity when the surrounding area is air would be smaller than the thermal conductivity when the surrounding area is filled with a liquid, so it would be possible to assess that there are leaks when Rb reaches 150% of Ra, for example.

(0023)

(EFFECT OF THE INVENTION)

According to the present invention, the ambient temperature of the temperature sensor for liquid leak detection is measured and the quantity of heat supplied to the temperature sensor for liquid leak detection is maintained at a constant level, so it is possible to accurately detect liquid leaks even when the ambient temperature changes. Moreover, the invention further makes is possible to accurately detect liquid leaks even when the ambient temperature changes by measuring the ambient temperature of the temperature sensor for liquid leak detection and directly measuring the quantity of heat supplied to the temperature sensor for liquid leak detection. Furthermore, the present invention makes it possible to accurately detect liquid leaks even when the ambient temperature changes by measuring the ambient temperature of the temperature sensor for liquid leak detection and maintaining the difference between the temperature of the temperature sensor for liquid leak detection and the ambient temperature at a constant level.

(BRIEF DESCRIPTION OF THE DRAWINGS)

(FIGURE 1) is a block diagram of an embodiment of the liquid leak detector of the present invention.

(FIGURE 2) is a block diagram of a second embodiment of the liquid leak detector of the present invention.

(FIGURE 3) is a block diagram of a third embodiment of the liquid leak detector of the present invention.

(FIGURE 4) is a diagram showing the basic principle of conventional heat dissipation type liquid leak detectors.

(FIGURE 5) is a block diagram of the power monitor.

(EXPLANATION OF REFERENCES)

1 – – – temperature sensor for liquid leak detection
2 – – – temperature sensor for ambient temperature measurement
4 – – – reference temperature storage mechanism of the temperature sensor for liquid leak detection
5 – – – reference temperature storage mechanism of the temperature sensor for ambient temperature measurement
7, 8, 10 – – – comparators
12 – – – heater
13 – – – current amplifier
14 – – – power monitor
15 – – – power setter
16 – – – power controller

(FIGURE 1)

[see source for figure]

1 temperature sensor for liquid leak detection
2 temperature sensor for ambient temperature measurement
4 reference temperature storage mechanism of the temperature sensor for liquid leak detection
5 reference temperature storage mechanism of the temperature sensor for ambient temperature measurement
7 comparator
8 comparator
10 comparator
12 heater
13 current amplifier
14 power monitor
15 power setter
16 power controller
Q heat quantity
T0l – T0a ambient temperature difference
ΔT temperature difference

(FIGURE 2)

[see source for figure]

1 temperature sensor for liquid leak detection
2 temperature sensor for ambient temperature measurement
12 heater
14 power monitor
23 thermal resistance reference value storage mechanism
25 comparator
27 thermal resistance finder
29 comparator
Q heat quantity

(FIGURE 3)

[see source for figure]

1 temperature sensor for liquid leak detection
2 temperature sensor for ambient temperature measurement
12 heater
14 power monitor
23 thermal resistance reference value storage mechanism
27 thermal resistance finder
30 comparator
31 comparator
33 temperature setter
35 heater drive circuit
39 comparator
Q heat quantity

(FIGURE 4)

[see source for figure]

41 temperature sensor
[below 41] liquid
43 comparator
[left of 43] output voltage
45 zero-point storage mechanism
[right of 45] reference voltage
Q heat quantity

(FIGURE 5)

[see source for figure]

51 resistance
53 thermistor
55 voltmeter